Algorithm–Driven Design of Robot Kinematic Layouts for Safe Autonomous CASEVAC

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Introduction

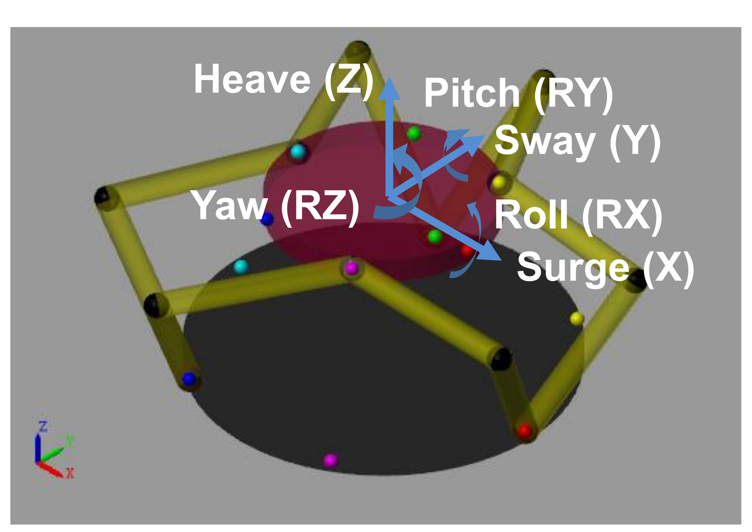
- Autonomous casualty evacuation (CASEVAC) is a promising approach for rescuing casualties in hazardous environments.
- However autonomous platforms are not optimized for casualty safety, exposing patients to harmful vibration and shock.
- Robotic isolation systems can isolate the motion of a casualty on a litter from the platform, but motorized approaches are often too heavy and power-intensive for field deployment.
- Semi-passive systems that use controllable passive elements (e.g., springs and dampers) are lighter and require less energy than motors, thereby increasing their ability to be deployed in the field.
- However, semi-passive systems are underactuated and isolation of the casualty from the platform will depend heavily on the constraints and coupling at the robotic linkages.

Objective

- Determine kinematic layouts for a litter interface for transport stabilization (LIFTS II) system that remains portable and compliant while providing isolation between the casualty and platform in all required degrees of freedom.

Methods

- In MATLAB Simscape we evaluated robot kinematic layouts using genetic algorithms.
- The genetic algorithm has been configured to optimizes the:
  - Linkage #
  - Linkages length
  - Attachment points
  - Litter position
  - Litter size
  - Platform size.



Compliance Matrix (***C***)

Output DOF (i) \ Input DOF (j)	X	Y	Z	RX	RY	RZ
X	1.00	0.00	0.00	0.00	2.39	0.00
Y	0.00	1.00	0.00	-2.39	-0.00	0.00
Z	0.00	0.00	1.00	0.00	0.00	0.00
RX	-0.00	-0.42	-0.00	1.00	0.00	0.00
RY	0.42	0.00	0.00	0.00	1.00	0.00
RZ	0.00	0.00	0.00	-0.00	0.00	0.00

Dimensionless [% Task]

- For candidate configurations, the simulation applies perturbations and tracks the litter motion over six degrees of freedom to construct a compliance matrix (**C**).
- The genetic algorithm then altered these variables to achieve a desired output motion between degrees of freedom at the litter (**T**).

Results

- Genetic algorithms were run to determine the ideal configurations 6-, 5-, 4-, and 3-arm robots with different joint types:
  - 24 populations/generation, the top 5 configurations are passed to the next generation.
  - The design input (**T**) was set to have uncoupled motion between heave, roll, and pitch.

$$\text{SVD}(\boldsymbol{C}) \Longrightarrow U\Sigma V^T$$

U = output DOF
Rank(Σ) = total DOF

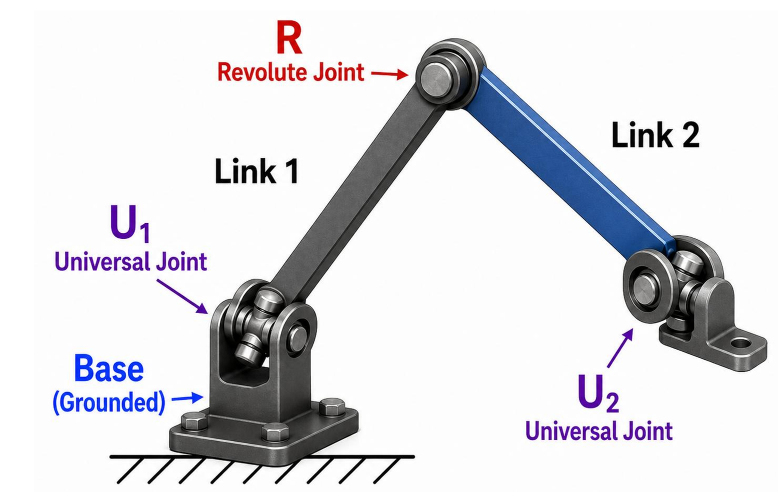
Design Input

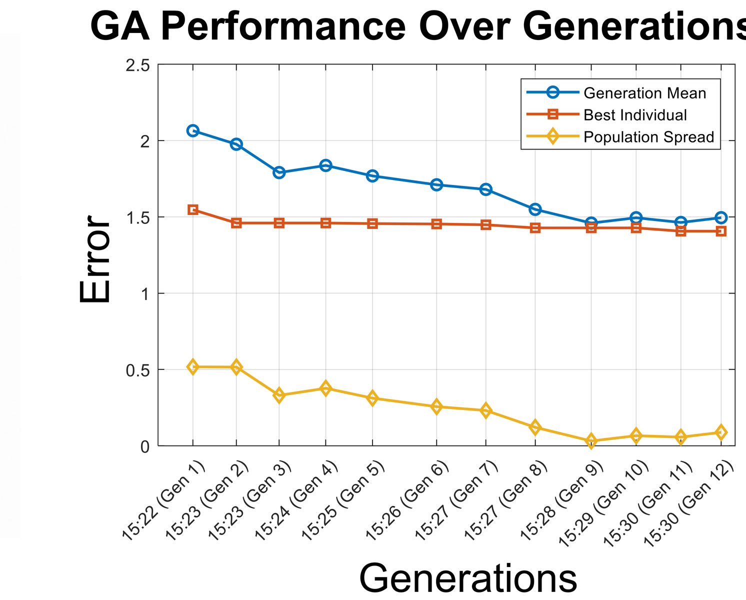
```
T =
[0 0 0;
 0 0 0;
 1 0 0;
 0 1 0;
 0 0 1;
 0 0 0]
```

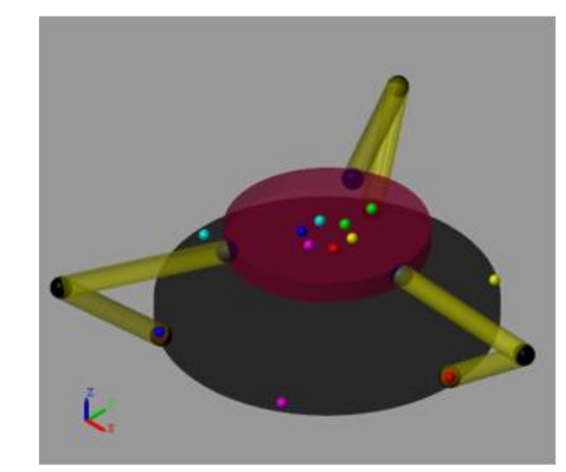
Heave Roll Pitch

Output Configuration Error

Universal-Revolute-Universal (UHU) Linkages







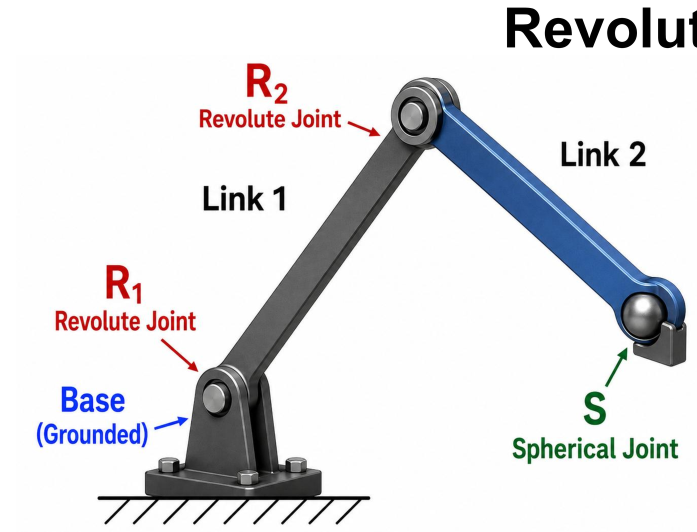
Compliance Matrix (***C***)

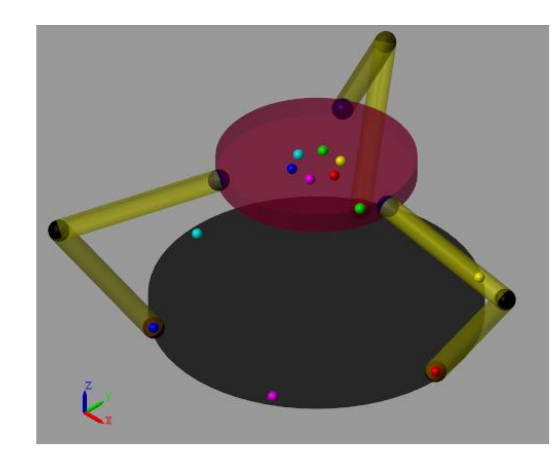
Output DOF (i) \ Input DOF (j)	X	Y	Z	RX	RY	RZ
X	1.00	-0.01	-0.00	-0.00	1.29	0.00
Y	-0.01	1.00	0.00	-0.43	0.01	0.00
Z	-0.02	0.01	1.00	0.01	0.16	0.00
RX	-0.00	-0.73	0.01	1.00	-0.02	0.00
RY	0.77	0.00	0.02	0.01	1.00	0.00
RZ	0.00	-0.02	0.00	-0.01	0.00	0.00

Dimensionless [% Task]

- This configuration has independence in the Z axis, and coupling in the X and RY axes, and Y and RX axes

Revolute-Revolute-Spherical (RRS) Linkages





Compliance Matrix (***C***)

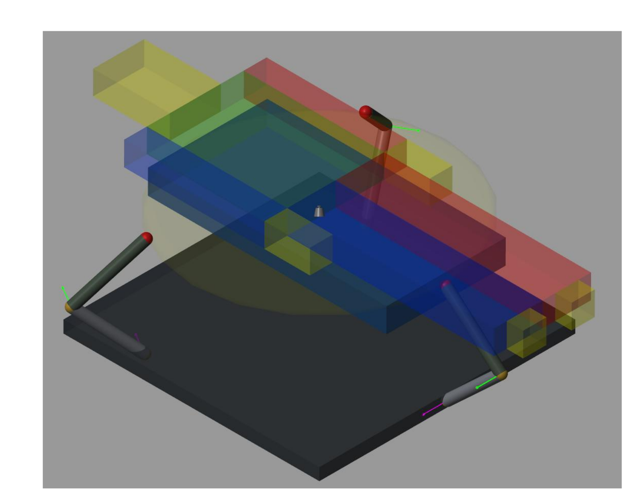
Output DOF (i) \ Input DOF (j)	X	Y	Z	RX	RY	RZ
X	0.00	0.00	-0.00	0.00	-0.00	0.00
Y	0.00	0.00	-0.00	-0.00	0.00	0.00
Z	0.00	0.00	1.00	0.00	0.00	0.00
RX	0.00	0.00	-0.00	1.00	-0.00	0.00
RY	0.00	0.00	-0.00	0.00	1.00	0.00
RZ	0.00	0.00	0.00	-0.00	0.00	0.00

Dimensionless [% Task]

- Robots with three RRS linkages achieved independent motion over heave, roll, and pitch. The robot is rigid against all other input motions.

Discussion

- We successfully created a testbed for developing semi-passive robotic systems and identified configurations for autonomous CASEVAC.
- This flexible framework is now being applied to determine the actuator requirements (i.e., stiffness and damping) at the joints of the robot to achieve isolation between the litter and platform.



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